**Multi-Criteria Assessment**

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**Adoptability of sustainable intensification options for the Koutiala context**

SUMMARY

*Sustainable intensification (SI) is seen as a pathway to overcome pressures and challenges for agricultural systems in West-Africa. But adoption of promising SI options often remains low. Based on literature, a framework with indicators of adoptability is proposed to visualise bottlenecks, strengths and weaknesses of technologies with regard to their adoption potential. Indicators related to multiple criteria were selected.*

*In this rapport two examples (maize-cowpea intercropping and stall feeding of dairy cows) out of the basket of options proposed for the local context in the cotton zone of southern Mali is evaluated on adoptability. The objective is to reveal oportunities and bottlenecks for adoption, as well as information gaps. On the other hand, by applying the adoptability framework for a concrete case study we also aim to uncover difficulties and unclarities in the construction of framework itself.*

*For maize-cowpea intercropping, labour cost and market access are possible bottlenecks for adoption. The interaction with the livestock component is crucial for determining the adoption potential of the maize-cowpea option. Compared to intercropping, dairy production is facing more constraints that might stand in the way of its adoption. Especialy with regards to labour and input needs, and economical factors (market access, demand, value chains) hurdles need to be taken. Overall, the opportunities and bottlenecks of the two options are similar to the general West African situation for legume intensification and increased dairy production.*

*The framework offers a good starting point for discussion and the identification of knowledge gaps.*

1. Background and problem statement

Agriculture remains a crucial livelihood strategy in sub-Saharan Africa (Alobo 2015), but the agricultural system is confronted with several challenges. For example, in many areas of West Africa, demographic growth led to the decrease of long-duration fallow periods (Andrieu et al. 2015; Traore et al. 2015), which implies less and degraded rangelands for livestock, declining soil fertility and thus impaired crop yields. Also, demographic growth goes hand in hand with increasing demands for food, feed and fuel (Herrero et al. 2010), enlarging pressure on natural resources. Additionally, expected climate change is a threat for agricultural productivity and growth (Andrieu et al. 2017).

The demographic pressure and climate threat ask for adaptation in smallholder farming systems (Douxchamps et al. 2016). Sustainable intensification (SI) offers options to intensify food production and be resilient to climate stress, without increasing pressure on the natural environment (Vanlauwe et al. 2014). There are three intensification concepts used in literature, that describe a similar objective: sustainable intensification (SI), ecological intensification and agroecological intensification (AEI). Wezel et al. (2015) synthesised a definition for the different concepts that explain the overlap between them (Table 1). The term SI will be used for uniformity, but when reviewing literature, technologies and practices that were designed following one of the other two paradigms will also be included.

Table 1: Definitions of three intensification concepts according to Wezel et al. 2015

|  |  |
| --- | --- |
| **Concept** | **Definition** |
| Sustainable intensification (SI) | Producing more from the same area of land while conserving resources, reducing negative environmental impacts and enhancing natural capital and the flow of environmental services. |
| Ecological intensification | Increasing food production while reducing the use of external inputs and minimising negative effects on the environment by capitalising on ecological processes and ecosystem services from plot to landscape level |
| Agroecological intensification (AEI) | Improving the performance of agriculture while minimising environmental impacts and reducing dependency on external inputs through integration of ecological principles into farm and system management |

In the African smallholder context agronomic technologies or practices that have shown potential to increase productivity and farmers’ livelihood often have limited uptake (e.g. Wossen et al. 2015; Cooper et al. 2008; Vlek 1990). The implementation of a technology or practice is guided not only by the profitability of it, but also by the perceived risks (Schlecht et al. 2006) , the objectives of farmers and constraints as labour, equipment and policy. As well, the research methodology followed when testing a technology or option, can play a role. Technologies are often tested at plot or field level where constraints at farm level may not arise (Giller et al. 2011).

Adoption is a concept often used to describe this uptake. (Woittiez et al. 2015) define adoption as “*the long-term integration of a technology or part of a technology into the set of household livelihood activities, measured in terms of well-defined and quantifiable indicators*.” Glover et al. (2016) warn for a rigid view on the concept of adoption when used as a measure of technological change in African agriculture. The dynamics of change and diversification of the technological repertoires are complex, and cannot be seen as a linear process. The technology can be only partially adopted or adapted, or be implemented on the farm at different intensity levels in time or space. They found many adoption studies don’t address those different aspects and lack transparency on their definition of adoption.

Glover et al. (2016) advocate for a more nuanced understanding of the impacts of agricultural research and technology development. An important question to answer is “*under what circumstances and conditions does adoption of technology result in increased agricultural productivity?*”

Woittiez et al. (2015) propose a framework for *ex-ante* analysis of sustainable intensification technologies and their opportunities and challenges for implementation. Derived from a literature study of SI options in West Africa, they define a list of criteria of adoptability. Adoptability of a technology is explained as “*a qualitative assessment of the potential of a technology to be adopted in a specific target system*”. This framework consists of criteria assessing costs and expected outcome of implementation. They serve to illustrate the opportunities of the technology as well as the likely bottlenecks for implementation, and thus help us to understand decision making of farmers.

1. Objective

In this report two SI options, that proved promising for Koutiala, Mali, will be evaluated on its adoption potential, using a range of criteria of adoptability provided by Woittiez et al. (2015). The objectives of this exercise are:

1. Assess adoptability of an SI option targeted to the local context of Koutiala

Will this exercise reveal bottlenecks for adoption that were not yet addressed during the development of the option? The assumption is that our multi-criteria assessment of an SI technology or practice will increase our understanding of the adoption potential.

In a later stage of research, this analysis could be compared with actual information *(ex-post)* on adoption and adaptation in the Koutiala region. An hypothesis to test is “an option has most chance to be adopted if there are less criteria that indicate a bottleneck”

1. Proof-of-concept adoptability framework

The exercise will also give insight in the benefits and difficulties of the framework. Is the framework easy to use and how can it be improved?

In a later step it can be explored how it relates and/or overlaps with other frameworks that evaluate the fit of a technology to a local context (e.g. SI indicators by (Smith et al. 2017) and Marinus et al. (in press) (not in this report).

1. Indicators of adoptability

In Woittiez et al. 2015 21 indicators on adoptability were proposed based on a large body of literature on sustainable intensification in West Africa. These indicators are categorised by enabling conditions and costs (both biophysical and socio-economic), and expected outcomes and benefits of implementation of the technology (Table 2). They form a framework to capture the main elements that determine whether or not a certain technology fits to the local context.

A traffic-light colour code was introduced to visualise the level of costs and benefits (Table 2). In Woittiez et al. 2015, four example technologies are discussed specifically for West Africa: Zai (improved planting pits), microdosing, Intercropping or rotation with legumes, and small-scale dairy production.

The colour-coding was based on qualitative information from case studies. No thresholds or guidelines were set to determine the indicator value (colour), which makes it a subjective process.

Table 2: Framework with indicators of adoptability (after Woittiez et al. 2015)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Category** | | **Indicator** | **Category** | | **indicator** |
| Enabling conditions and cost | Biophysical conditions | Land area | Outcomes and benefits | Direct outcomes | Risk |
| Rainfall, Aridity Index (AI), length of rainy season | Nutrition |
| Availability of water sources | Short-term financial results |
| Soil fertility, quality | Long-term results |
| Rangeland extent, quality | Indirect outcomes | Ecosystem service provision |
| Inputs | Internal, re-allocated inputs |
| External, purchased inputs |
| Labour |
| Information and skills |
| Economic | Credit availability |
| Markets |
| Price level and stability |
| Demand |
| Institutional | Policy |
| Land tenure |
| Social, cultural | Culture, tradition |
| *Colour code*  *enabling cost* | *Medium/high, or high costs* | *Colour code benefits* | *Low benefits* |
| *Medium enabling costs* | *Low/medium benefits* |
| *Low/medium enabling costs* | *Medium benefits* |
| *Low enabling costs* | *High benefits* |

1. Koutiala case study: basket of options

In Koutiala, located in the cotton zone of southern Mali, agricultural activities remain the main source of income for households (Losch et al. 2012). Apart from generating income, the main objective of these farmers is to sustain their food self-sufficiency with the cultivation of maize, millet and sorghum (Bosma et al. 1999). However, crop yields are stagnating and labour productivity has decreased since the nineties (Falconnier et al. 2015). During this period only a minority of farms (17%) simultaneously improved crop yield, labour productivity and food self-sufficiency status (Falconnier et al. 2015).

Past research proposed a range of SI options for Koutiala, some of them targeting a specific niche depending on the resource endowment of the farm (‘best-fit’ options) (Table 3).

Table 3: Basket of SI options, at plot and farm level, for smallholder farmers targeted to the local context in the Koutiala region, Mali (not exhaustive)

| Level | **Plot/animal level** | | | | | **Farm level** | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Type of SI option | Option | Description | Analysed indicator | Niche | Source | Option | Description | Analysed Indicator | Niche | Source |
| Management of yield-limiting factors | Avoid delay in planting | By avoiding a delay in planting, recommended fertilizer use and use of targeted varieties, a negative effect of the predicted climate change (rcp 4.5 and rcp 8.5) can be (partially) avoided. | Grain yield | Especially for millet and maize | *(Traore et al. 2017)* | / | / | / | / | */* |
| Legume cultivation | Cowpea fodder variety | The biomass production of cowpea fodder doubled on black soils, compared to gravelly soils | Fodder yield | Black soils | *(Falconnier et al. 2016)* | Diversifying crop choice with soybean and cowpea | Replacing sorghum by soybean or cowpea can increase gross margin without compromising food self-sufficiency (FSS) | FSS,  Gross margin | For LRE and MRE farms[[1]](#footnote-1) | *(Falconnier et al. 2017)* |
| Intercrop  Maize-cowpea | the additive maize/cowpea intercropping option resulted in no maize grain penalty, and more cowpea fodder production compared with sole maize. | Grain yield,  Fodder yield | After cotton or maize | *(Falconnier et al. 2016)* | Intercrop maize-cowpea, | Intercrop in the right niche, combined with stall feeding can increase gross margin without compromising FSS | FSS,  Gross margin | For HRE and HRE-LH farms1  If combined with stall-feeding | *(Falconnier et al. 2017)* |
| Animal production | Stall feeding of cattle during dry season | The animal production and growth of the cow-calf pairs increased during the dry season when they were stall fed with legume fodder and cottonseed cake during the dry season | Milk and manure production per animal,  Animal weight |  | *(Sanogo 2010)* | Stall feeding of cattle during dry season | Farmers may (partly) replace cotton production for fodder production if price of cotton remains poor and milk price relatively strong | Milk production,  Profitability | “better-off farmers”,  *Good cross price elasticity of cotton and milk* | *(de Ridder et al. 2015)* |
| *See above* – if combined with intercropping maize-cowpea in the right niche | FSS,  Gross margin | HRE, HRE-LH,  If combined with intercrop | *(Falconnier et al. 2017)* |
| A higher milk production contributes to financial benefits of stall feeding dairy cows during the hot dry season | Gross margin | “Large farms” | *(Sanogo 2010)* |

1. Applying the adoptability framework for Koutiala case study

The scope of this report is limited to “maize-cowpea intercropping”, and the option of “stall feeding cattle during the dry season” which are closely related. This choice is partly based on data availability. A second reason is both options’ contribution to crop-livestock integration, which is a strategy to support intensification of crop and/or livestock production (Sumberg 2003).

In the following section these technologies from the basket of options for the Koutiala region will be held against the light of the proposed adoptability framework (Table 4). The analysis for West Africa for the similar SI option by (Woittiez et al. (2015) is included in the table of analysis and compared with the Koutiala case study. Before addressing the indicators, the research findings on maize-cowpea intercropping and stall feeding of dairy cows as part of the basket of options for Koutiala, are described briefly.

Maize-cowpea intercropping

On-farm trials in the period 2012-2014 showed an average total LER (Land Equivalent Ratio) greater than one in maize-cowpea intercropping for all the tested treatments. Two cowpea varieties (fodder variety and grain variety) were tested in two different intercropping patterns (additive and substitutive). Nevertheless, only with the additive pattern, cultivated after maize or cotton, there was no maize grain penalty (Partial Land Equivalent Ratio, or pLER>1) added on top of the gain from the cowpea fodder production. More details on the trials and results are described in Falconnier et al. (2016).

In 2016 and 2017 the defined niches at plot level were also tested on a bigger scale (0.25ha). Only a limited set of five pairs of fields was followed (five fields of maize-cowpea after cotton or maize, and five after sorghum or millet). The same exercise was conducted for fields with sorghum-cowpea intercropping. First results, and farmers’ comments, correspond to the findings above (better grain and fodder yield after cotton or maize). Farmers indicated that they prefer to intercrop cowpea, rather than to cultivate sole cowpea.

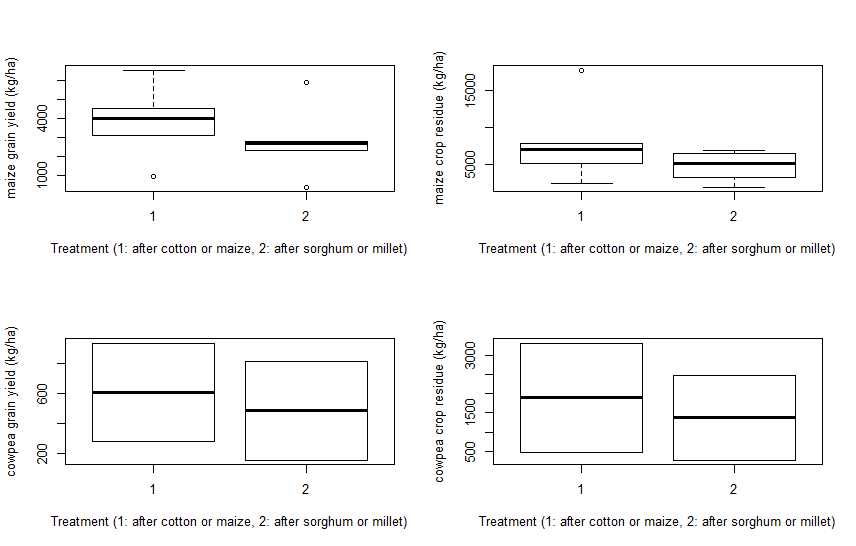


Figure 2: Fresh weight yields of maize-cowpea demonstration fields of 0.25ha in 2016 and 2017 (n=5), where fields that are sown after cotton or maize in the previous year (treatment 1) are compared to fields that were sown after sorghum or millet (treatment 2)

At farm level, a re-design exercise was conducted together with farmers during a three year iterative co-learning cycle (2013-2015). The re-design that farmers imagined differed per type of farm[[2]](#footnote-2). This was followed by an *ex-ante* assessment of the re-designs analysing gross margin and food self-sufficiency. Maize-cowpea intercropping, combined with stall feeding was interesting for higher resource endowed farmers. If maize-cowpea intercropping in the right niche would replace all maize, HRE-LH farmers could obtain a 20% increase in whole farm gross margin, with on average stall feeding 93% of their lactating cows. HRE farmers would we able to feed 92% of lactating cows, leading to a 26% increase in average farm gross margin. MRE and LRE farmers didn’t mark this option as interesting. More details on farmers’ feedback and the modelling exercise are given in Falconnier et al. (2017).

One year after the cycle with research-guided trials, an assessment was made how farmers implemented maize-cowpea intercropping, providing information on additional constraints and benefits at field and farm level (Coulibaly 2015). Both farmers that participated in the earlier trials, and non-participating farmers were included. This assessment was done while the project was still running in the area, so it evaluates ‘try-outs’ by farmers, rather than adoption which needs to be evaluated in the longer run (Misiko et al. 2008). Off course maize-cowpea intercropping is not a new technology for the region, but niches and management practices were sharpened through research.

Maize-cowpea intercropping was frequently practiced (83% of 103 surveyed farmers), but a lot of variability existed in field management. Nevertheless, it can be concluded that most farmers follow an additive pattern (97%), and that the fields are fertilised (82%) with both organic fertiliser and with a combination of DAP and urea, although quantities varied. When fertiliser was used, the interquartile range of the N applied through mineral fertiliser ranged between 38 and 68 kg/ha, with the average being 62 kg N per ha. There was no information captured on the intensity of implementation (area of intercropping on the farm), nor on the use of niches. The main constraint mentioned for maize-cowpea intercropping is the effort it takes (for 51% of farmers), and more specifically the hilling (‘buttage’) (62%) (Coulibaly 2015).

In Table 4 the maize-cowpea option for Koutiala is evaluated according to the adoptability indicators, and compared to the more general analysis of intensive legume cultivation in West Africa.

Because of the lack of clear indication on how to implement the colour-coding for the indicators, the level (colour) of Woittiez et al. 2015 was used as the starting point. When the analysis of the case study differed from the overall analysis for West Africa, the level was shifted up or down.

Table 4: Adoptability indicator framework for 'intensive legume cultivation' in West-Africa (Woittiez et al. 2015) and the maize-cowpea intercropping option for Koutiala, Mali

| **Category** | | **Indicator** | **Analysis (Woittiez et al. 2015):**  **Intensive legume cultivation in West Africa** | **Analysis case study:**  **Maize-cowpea intercropping in Koutiala** |
| --- | --- | --- | --- | --- |
| Enabling conditions and costs | Land, natural resources, climate | Land area | In fields that are already under cultivation | In fields that are already under cultivation:  The niche requires to replace maize by maize-cowpea intercropping. |
| Rainfall, Aridity Index, length of rainy season | Depending on water requirements of legume variety | The option was tested for 3 years, and pLER>1, for all rainy seasons. So rainfall variability did not seem to affect the positive effect of intercropping at field level (Falconnier et al. 2016) |
| Availability of water sources | (This is relevant especially for irrigation practices) | NA - *no irrigation* |
| Soil fertility / quality | Sufficient P availability, Mo, some nutrients for establishment | Agronomic performance was tested on three soil types that farmers identified, namely black, sandy and gravelly soil. The soil type did not affect the performance of the maize/cowpea intercropping options, showing the low inter-annual risk for farmers and the suitability of the option on all soil types in the area (Falconnier et al. 2016). |
| Rangeland extent / quality | NA | NA |
| Inputs | Internal / re-allocated inputs | Manure or mulch is beneficial, but not essential if P fertiliser is available | When applied in the right niche, the intercropping benefits from residual effects of fertiliser application to cotton or maize earlier in the rotation (Falconnier et al. 2016; Ripoche et al. 2015)  During the plot trials no organic fertiliser was applied (Falconnier et al. 2016). So the option does not require organic fertiliser to be promising.  Nevertheless, farmers have the habit of applying organic fertiliser mainly on their cotton and maize fields, including their fields of maize-cowpea intercrop (diagnostic study 2013 and 2017; survey on intercrop practices, 2015)  Animals are allowed to graze on fields after harvest. Legume crop residues are used for cattle feeding. Crop residues are not used as mulch. |
| External / purchased inputs | P fertilisation is essential for legume growth and N fixation | Fertiliser is targeted to maize and cotton. So changing from maize to maize-intercropping doesn’t require extra use of fertiliser.  Farmers have the habit of applying DAP and Urea on their intercropped fields (diagnostic study 2017; survey on intercrop practices, 2015).  The plot trials were also conducted with fertiliser application (Falconnier et al. 2016) |
| Labour | Extra labour required for sowing, harvesting and application of pesticides | 51% of farmers indicate labour and effort needed as a constraint affecting the level of cowpea-maize implementation.(survey on intercrop practices, 2015)  Another constraint mentioned by farmers is the similar timing of fodder harvest and cotton harvest. If cowpea would be harvested later, this would affect quality and quantity of the fodder (falling leaves) (Sanogo 2010).  Farmers indicate that sickness of people or oxen at sowing time is something they worry about as it would determine the production obtained. This indicates that in general labour pressure is high. (focus group discussions, 2017) |
| Information and skills | Basic skills required, such as knowledge about sowing densities and management | A participatory approach lays at the basis of the research, both at field and farm level. A co-learning cycle was applied when re-designing the farm system. Integrating farmers in the process fosters learning and understanding of experiments. (Falconnier et al. 2017; Misiko et al. 2008) |
| Economic | Credit availability | Depending on cultivation intensity, credit may be required for the purchase of seed, P fertiliser and pesticides | The tested option requires application of mineral fertilizer.  Access to fertiliser and seeds is facilitated by the Compagnie Malienne pour le Développement du Textile (CMDT) for cotton producting farmers (Theriault and Tschirley 2014; Degnbol 2001).  Due to imperfections in markets (e.g. credit rationing) and high transaction cost most smallholders, in particular the poorest ones, lack (or lack access to) financial resources to buy much other inputs (e.g. fertilizers), services (e.g. renting tractor for plowing fields) or equipment (Annex 2). |
| Markets | Markets must be available for purchase of P fertiliser and seeds and for the sale of legume grains | Investment in the cotton sector by the Compagnie Malienne pour le Développement du Textile (CMDT) has led to improved market access that has been beneficial to all smallholder farmers (Theriault and Tschirley 2014).  Nevertheless, farmers perceive they are at risk to obtain bad quality of seeds (in 3 out of 4 villages) and fertiliser (2 villages), as well as not getting hold of the fertiliser on time (3 villages). (focus group discussions, 2017) |
| Price level and stability |  | The extra cost for inputs was taken into account in the redesign exercise at farm level, still the option, within the right niche and for the right farm types, remained promising. (Falconnier et al. 2017) |
| Demand | Cultivation of legumes that cannot be sold is unattractive | Both maize and cowpea are mainly cultivated for farm consumption. Of total maize production, on average 93% is used for consumption. Only 3% of farms that produce cowpea grain are selling a share of it (30-60%) (household survey, 2014)  The objective of additional cowpea production is to be able to feed cattle with the haulms, not for selling. |
| Institutional | Policy | P fertiliser must be available | Access to fertiliser and seeds is facilitated by the CMDT for cotton producing farmers (Theriault and Tschirley 2014; Degnbol 2001) |
| Land Tenure | Prevention of grazing by livestock. Investment in soil fertility is more likely in case of secure tenure | In the project villages they feel the influence of population pressure on access to land, and pressure to regulate land rights (Coulibaly et al. 2013; Coulibaly et al. 2017)  Animals are allowed to graze on fields after harvest. Legume crop residues are used for cattle feeding. |
| Social/Cultural | Culture / Tradition | Part of the crop residue must be left in the field in order to improve soil properties. Animal grazing of residues must be limited. The area under cereal cultivation may be reduced. Acceptance of new feed types may be an issue | Traditionally cereals are intercropped with legumes, although in low densities.  83% of farmers cultivate maize and cowpea in some level of intercropping. Although this gives no information on the use of the niches, nor management practices, it indicates that the specifics of the proposed option could be easily accepted (Coulibaly 2015).  Animals are allowed to graze on fields after harvest. Legume crop residues are used for cattle feeding. |
| Outcomes and benefits | Direct outcomes | Risk | Cultivation of drought resistant legumes such as cowpea | The season and soil type did not affect the performance of the maize/cowpea intercropping options, showing the low inter-annual risk for farmers and the suitability of the option on all soil types.  After cotton and maize, a maize grain pLER of at least one was achieved by half of the farmers and by only 22% of farmers after other crops (Falconnier et al. 2016). So when the option is not applied in the right niche, the risk of the option not being beneficial increases. |
| Nutrition | Legumes provide protein an dietary diversity | Cowpea grain provides protein and dietary diversity. But in this case, cowpea is cultivated mainly with the objective to provide fodder for stall feeding cattle.  The nutritional benefit could be achieved through the additional production in milk (see discussion). |
| Short-term financial results | Depending on P application and overall intensity of the system. Higher in combination with livestock fattening | Extra fodder production is up to 0.29 and 1.38 t ha−1 on average for cowpea grain variety and cowpea fodder variety respectively, if used in the right niche (Falconnier et al. 2016)  If applied in the right niche, and combined with stall feeding of lactating cows, HRE-LE farmers could obtain a 20% increase in whole farm gross margin, and HRE farmers 26% (Falconnier et al. 2017)  There is no information on financial benefits for MRE and LRE farms. |
| Long-term financial results | Additional soil fertility management techniques are required to sustain production. Higher in combination with livestock fattening | *No information on long-term financial results.* |
| Indirect outcomes | Ecosystem service provision | N-fixation, increased diversity | Leaving crop residues in the field is important for increasing soil N and SOM (Giller and Cadisch, 1995). Farmers have limited scope to allocate crop residues for soil cover, since they are needed for animal feeding. This trade-off between animal production and soil C was also described for Zimbabwe by Rusinamhodzi et al. (2015) |

Stall feeding of dairy cows

In Southern Mali, milk yields of indigenous breeds are poor, averaging <1 kg/day per cow over the lactation period, particularly during the dry season when there is a feed shortage (De Ridder et al. 2015). Small-scale dairy production can benefit from legume cultivation. If feeding constraints can be overcome, dairy production is an option for farmers in Southern Mali to improve food self-sufficiency and/or income.

In the Koutiala region, trials were conducted on different feeding regimes of lactating cows during the dry season. Stall feeding of dairy cows with legume fodder and cottonseed cake during the dry season increases animal production and growth of cow-calf pairs (Sanogo 2010). Milk and manure production per animal, as well as animal weight increased when animals where stall fed.

During the trials local breeds (N’Dama and Méré, which is a crossbreed of Zebu and N’Dama) were stable fed, given a supplement or only fed through grazing (control) during the dry season. Cows that were stable fed were given 2kg fodder (cowpea or stylosanthes), 2kg cottonseed cake and 4kg cereal residue per day. Over a period of three months (March-June) cows that were stall fed gained 3kg, while the other groups experience weight loss (14kg for supplemented cows, 25kg for grazing cows). Cumulated milk production was 152 L per stable fed cow, and 85 L for supplemented and 44 L for grazing dairy cows. Also for manure production these differences were noticed (248kg for stable fed cows, 159kg supplemented , 131 kg for control) (Sanogo 2010). During a participatory evaluation of the trial, some farmers appreciated the increased milk production when stall feeding the cows, but others focused more on the weight gain of cow and/or calf, or the increased manure production. All these are short-term effects, but farmers also appreciated the possible long-term effects of a better reproduction rate.

The possibilities and effects for stable feeding at farm level were described in de Ridder et al. (2015) and Falconnier et al. (2017). De Ridder et al. (2015) conducted a modelling exercise where different proportions of land allocated to cotton were replaced by cowpea producing fodder for lactating cows. Only cotton was replaced, because both cotton and milk can provide cash income, and to not affect the cereal production of farmers which they grow to reach food self-suffiency. Supplemented feed for cattle and different levels duration of stall feeding were compared to the control of year-round grazing. Keeping lactating cows stall-fed during the dry season with hight quality supplement feed increased the partial annual revenue (income from milk and cotton) of medium and large farms with 16% and 5% respectively. These scenarios are promising when the price of cotton would stay the same or fall, and the price of milk would stay the same or rise. When the cotton price would rise, cotton production would be more profitable in all scenarios. The farm analysis by Falconnier et al. (2017), where the extra cowpea fodder produced by replacing maize by maize-cowpea intercropping is used to stall feed lactating cows, is described in more detail in the previous chapter. High resource endowed farmers would we able to gain a 26% increase in average farm gross margin through. So, both papers describe stable feeding of dairy cows as a promising option for better resource endowed farmers, with respect to income and without compromising food self-sufficiency.

Best practices and niches have been described for the option of maize-cowpea intercropping, in order to increase cowpea fodder yield (field level) and gross margin at farm level (this in combination with dry season stall feeding of cows). It is mainly high resource endowed farmers that can benefit. Nevertheless, other constraints, risks and possibilities that could influence adoptability are further discussed in the table below.

**Table 5: Adoptability indicator framework for 'small-scale dairy production' in West-Africa (Woittiez et al. 2015) and the dry season stall feeding option for Koutiala, Mali**

| **Category** | | **Indicator** | **Analysis (Woittiez et al., 2015):**  **Small-scale dairy production in West Africa** | **Analysis case study:**  **Dry season stall feeding of lactating cows in Koutiala** |
| --- | --- | --- | --- | --- |
| Enabling conditions and costs | Land, natural resources, climate | Land area | Intensification per unit land is required, especially in peri-urban regions. Land is needed for production of feed | Feed production through intensification per unit land is an option when applied in the right niche. Additional production of cowpea fodder without compromising maize grain penalty can be achieved through maize-cowpea intercropping in an additive pattern after maize or cotton (Falconnier et al. 2016). |
| Rainfall, Aridity Index, length of rainy season | Good quality natural pastures and feed supplements (crop residues or cottonseed cakes) are needed | During the dry and hot season there is a feed shortage due to declining natural grazing lands (de Ridder et al. 2015). Feed supplements (crop residues and cottonseed cakes) are needed. |
| Availability of water sources | Water must be available for drinking | Water is a limited resource during the dry season that can be a source of conflict between pastoralists and farmers (Benjaminsen et al. 2010; Turner et al. 2011). |
| Soil fertility / quality | Production of sufficient quantities of good quality crop residues is desirable | Crop residues are mainly used to feed livestock. These are left in the field and grazed by animals after harvest (November-June) (de Ridder et al. 2015)  This means crop residues are not returned to the soil. Stall feeding increases manure production (Sanogo 2010) that can be applied as organic fertiliser. |
| Rangeland extent / quality | High reliance on natural pastures in all systems. Additional feed sources are needed for milk production and quality | Expansion of cropland and increase in livestock number create land and grazing pressure and degradation of rangelands (Andrieu et al. 2015). |
| Inputs | Internal / re-allocated inputs | Crop residues for dry-season feeding | Crop residues are given to livestock. Intercropping maize-cowpea in the right niche can increase fodder production without compromising food self-sufficiency (Falconnier et al. 2017). |
| External / purchased inputs | Depending on system intensity and starting point. Main costs are for cattle purchase, feed, labour, housing, transport and veterinary interventions | The price of the feeding complements has a big effect on the revenue of farmers, since it represents 60 to 90% of the price for the stall feeding cost. An increase of 7% of the cottonseed cake cost, will lead to 11% less income per cow (Sanogo 2010) |
| Labour | Milking once or twice per day, feeding, milk sales and/or processing, transport, herding | Farmers see it as constraint that legume harvest has the same timing as cotton harvest. If cowpea would be harvested later, this would affect quality and quantity of fodder (falling leaves) (Sanogo 2010).  Household members are primarily occupied with cropping activities, and labour often lacks for livestock feeding and watering which is also time consuming (Falconnier et al. 2015). |
| Information and skills | Feeding, milking, disease and herd management, hygiene | Tasks related to feeding of livestock, are often handed over to children (Falconnier et al. 2015) |
| Economic | Credit availability | Credit may be needed for cattle purchasing, feed, labour, housing, transport and veterinary interventions | Credit is needed to purchase cottonseed cakes. The price of the feeding complements represents 60 to 90% of the price for the stall feeding cost. An increase of 7% of the cottonseed cake cost, will lead to 11% less income per cow (Sanogo 2010)  According to Pica-Ciamarra (2005), farmers face difficulties to access credit with financial institutions mainly due to the fact that they are mostly poor, generally lack collateral, are spatially scattered and that both parties are subject to high transaction costs (Annex 2). |
| Markets | Local or urban markets must be nearby, products have limited shelf life | The milk market chain remains rudimentary, although there are farmers from villages nearby urban centres that can sell milk to processors including cooperatives (de Ridder et al. 2015) |
| Price level and stability | High competition from imported milk products (powder), supplement prices are market dependent and affect profitability. Prices are seasonal | A shift in the farming system towards increased milk production is risky and would take a long time to fully develop (change in labour allocation and farming priorities). A precondition to gain full benefits of this, will be that prices for milk are stable over a longer period and favourable in comparison with cotton. Currently farmers prioritise cotton production for income. (de Ridder et al. 2015) |
| Demand | High investment costs, labour intensive | Frequency of meat and milk consumption is low in the rural setting of Southern Mali (Generoso, 2015)  In Southern Mali, maize, sorghum, and dairy products are becoming important income generators thanks to increasing outlets in nearby expanding cities (Corniaux et al. 2012; Kaminski et al. 2013). |
| Institutional | Policy | Support for establishment of small-scale processing units, veterinary support | Because of CMDT support, many farmers have increased the size of their herds. CMDT provided inputs, credit services for farmers, oxen for draught power and equipment for cultivation and guaranteed prices for cotton. These interventions led to an increase in the number of oxen for traction, and to investments in other cattle (Sanogo 2010).  In Mali, authorized veterinary agents are the main animal care providers based on a decentralized system that combines provision of public services (e.g. vaccination) and of private services. The use of private services by agro-pastoralists depends mostly on their financial capacity and their awareness of the importance of professional services for better an animal health. Currently, many agro-pastoralists have understood the importance of animal vaccination. However, they prefer to collaborate with agents on an informal basis anchored in the social relationship between them (Annex 2). |
| Land Tenure | Access to natural pastures required | Cropland expansion in Koutiala leads to increased grazing pressure on the remaining pastures (de Ridder et al. 2015, Sanogo 2010). |
| Social/Cultural | Culture / Tradition | Traditional systems tend to move towards increased herd size rather than production intensification | Frequency of meat and milk consumption is low in the rural setting of Southern Mali (Generoso, 2015)  Animal traction is the primary objective for farmers with cattle (Sanogo, 2010). So farmers might prefer to target feeding to draught oxen, and thus limit weight, over dairy cows. |
| Outcomes and benefits | Direct outcomes | Risk reduction | Large cattle herds serve as a buffer for unexpected occasions | Farmers keep cattle mainly for draft power and the function of insurance (Benjaminsen et al. 2010; Sanogo 2010) |
| Owning few crossbred cattle is risky in case of disease or market collapse | Local breeds (N’Dama) are less productive, but relatively tolerant to heat, trypanosomiasis and can survive on poor quality feed. Fulani Zebu and crossbreds cattle proved suitable for market-oriented farmers (Traore et al. 2018).  Nevertheless, the prevalence of diseases in the absence of veterinary care is risky for farmers, as livestock are an important factor in farmers’ livelihood (Ayantunde et al. 2014). |
| Nutrition | Addition of protein to the diet | Milk production can add protein to the diet. There is a trade-off between production of milk for consumption (nutritious diet) and for selling (adding income). |
| Short-term financial results | Depending on production intensity and management | Several studies have shown that high resource endowed farmers can increase income when stall feeding dairy cattle during the dry season. Fodder production is targeted in the right niches to not compromise food self-sufficiency (Falconnier et al. 2017; de Ridder et al. 2015; Sanogo 2010) |
| Long-term financial results | Depending on production intensity. Concerns exist about the sustainability of cottonseed cake production and about natural pasture degradation | *No information* |
| Indirect outcomes | Ecosystem service provision | Increased soil fertility, nutrient cycling. Risks: rangeland degradation | In the area crop residues are given to livestock and not returned to the field. Trials showed that in the case of stall feeding of dairy cows also manure production is increased. This can be used to fertilise fields.  Nevertheless, a similar study by Amadou (2015) claims only 15–58 % of the dry matter and nutrients provided through supplement feeds were recovered inmanure at the homestead. |

1. Discussion and conclusion

Adoptability of the options

The framework proved to be useful in pointing out information gaps (e.g. on credit availability, and long term financial results), and laying the finger on possible bottlenecks for future implementation of the SI option. In the case of maize-cowpea intercropping in the context of Koutiala, some possible bottlenecks are (i) the extra need for labour (although current information on labour cost is limited), (ii) market access (farmers worry about limited access to good quality seeds and fertiliser). According to Drechsel et al. (2005) the determinants for adoption that are often overlooked are returns to labour, investments costs, perceived risk, period between investment and returns, and cultural or historical barriers.

Important to note here is that at farm level, maize-cowpea intercropping is most promising in combination with stall feeding of dairy cattle (for HRE-LH and HRE farms), and interactions between those two options are reflected in both applications of the adoptability frameworks (Table 4 and 5). For some criteria the option seemed less promising as in the overall analysis for West Africa. But when the ‘stall feeding’ component of the option is taken into account together with the ‘maize-cowpea’ intercropping, this impression changes.

An interaction exists between the livestock and crop component for ‘nutrition’, ‘market demand’ and ‘financial returns’. For example, the direct contribution of the additional cowpea to improved nutrition is limited because it is mainly producing fodder for stall feeding. This stall feeding leads to higher milk production which contributes to either improved nutrition or higher financial returns, depending on the level of home consumption or milk being sold.

Compared to intercropping, dairy production is facing more constraints that might stand in the way of its adoption. Especialy with regards to labour and input needs, and economical factors (market access, demand, value chains) hurdles need to be taken.

Proof-of-concept of the adoptability framework

The available information and data does not allow for separate analyses for every defined niche. For example, the proportion of cowpea production that is used for consumption and for selling is not divided per farm type. This might mask underlying variation.

During the application of the framework, some methodological hurdles were faced. The main difficulty was related to missing objectively quantifiable indicators and a lack of reference values for determining the level of ‘adoptability’ for the different components. The lack of clear guidelines on how to apply the traffic light schemes makes colour-coding a very subjective and un-transparent process.

The framework tries to evaluate the adoptability based on general attributes of the system, with indicators that remain qualitative rather than quantitative. When frameworks have been developed for evaluating sustainability of agriculture, the use of specific objectives and quantitative parameters was often at the expense of a holistic evaluation of the system as a whole (Van Cauwenbergh et al. 2007).

These authors propose hierarchical framework with principles, criteria and indicators. Principles are related to the multiple functions of the agro-ecosystem, beyond the production function alone. Criteria are specific objectives and relate to the state of the system. They are easier to assess and indicators are linked to them. These indicators describe features of the state of the system in an objectively verifiable way. Procedures are set to measure or estimate the indicator value. Reference values describe the desired level for each indicator. This hierarchical structure could also be introduced to the adoptability framework to make norms more explicit. I suggest that the ‘adoptability indicators’ are rephrased as criteria, for which indicators and reference values are still to be defined.

The question then rises in how much the adoptability indicators will differentiate from indicators evaluating sustainable intensification, and whether it is useful to make a separate framework for the adoptability with such clearly defined indicators. This framework of adoptability was constructed with the objective to guide discussion on the opportunities and bottlenecks of SI options. In the current form, it should indeed be used as a starting point for discussion, as well as to discover knowledge gaps.

1. Literature

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1. Farms are grouped in four types based on indicators of resource endowment: High Resource Endowed farms with Large Herds (HRE-LH), High Resource Endowed (HRE) farms, Medium Resource Endowed (MRE) farms and Low Resource Endowed (LRE) farms (Falconnier et al. 2015). [↑](#footnote-ref-1)
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